— add-6

SAM-TR-66-55

AD 639638

AN EXPANDED TEST FOR SPEECH DISCRIMINATION UTILIZING CNC MONOSYLLABIC WORDS

Northwestern University Auditory Test No. 6

TOM W. TILLMAN, Ph.D.
RAYMOND CARHART, Ph.D.

June 1966

USAF School of Aerospace Medicine
Aerospace Medical Division (AFSC)
Brooks Air Force Base, Texas

AN EXPANDED TEST FOR SPEECH DISCRIMINATION UTILIZING CNC MONOSYLLABIC WORDS

Northwestern University Auditory Test No. 6

TOM W. TILLMAN, Ph.D.
RAYMOND CARHART, Ph.D.

FOREWORD

This report was prepared in the Auditory Research Laboratory of Northwestern University under contract No. AF 41(609)-2643 and task No. 775508. The paper was monitored by Captain James E. Endicott, ENT Branch of the USAF School of Aerospace Medicine. It was submitted for publication 1 April 1966. The work was accomplished between 16 January 1964 and 15 April 1965.

This report has been reviewed and is approved.

Harold V. Ellingson
HAROLD V. ELLINGSON
Colonel, MC, USAF
Commander

ABSTRACT

Northwestern University Auditory Test No. 6 is composed of four lists of 50 consonant-nucleus-consonant (CNC) monosyllabic words each. The construction of the test followed the same scheme employed earlier in the development of N.U. Test No. 4, a less extensive version using the same type of material. The four lists of N.U. Test No. 6 were given twice to each of two subject groups—one group with normal hearing and another with sensorineural hypoacousis. During each administration, six ascending presentation levels were used ranging from —4-dB to 40-dB sensation level.

The two groups yielded articulation functions highly similar to those obtained with the earlier test (N.U. Test No. 4). The new test (N.U. Test No. 6) appears to have good interlist equivalence and high test-retest reliability. It thus retains the desirable features of the earlier tool while doubling the inventory of items available for the measurement of phonemic discrimination.

AN EXPANDED TEST FOR SPEECH DISCRIMINATION UTILIZING CNC MONOSYLLABIC WORDS

Northwestern University Auditory Test No. 6

I. INTRODUCTION

In 1963, a new test for speech discrimination was described by Tillman et al. (4). It consisted of six randomizations of each of two 50-word lists and was designated Northwestern University Auditory Test No. 4. The monosyllabic words used in constructing the test were of the consonant-nucleus-consonant (CNC) variety and were selected from a pool of such words compiled by Lehiste and Peterson (1). The scheme of phonemic balance followed in constructing the two parent lists was described in detail earlier (4).

This new tool, N.U. Test No. 4, was utilized extensively in the Auditory Research Laboratories at Northwestern for a two-year period. It proved to be a valuable addition to the array of materials available for the measurement of phonemic discrimination. In both its original form and under conditions of differential filtering it has been shown to possess high interlist equivalence and good reliability. The major shortcoming of the test has evolved from the fact that the pool of test materials which it makes available is too restricted. Even with six equivalent forms of each list, the exploration of a large number of listening conditions cannot be accomplished without several repetitions of the various forms and lists. Such repetition, of course, adds variables such as learning factors which may exert differential effects over subjects.

Because of the limitation just described, it became desirable to revise and expand N.U. Auditory Test No. 4. The foremost consideration was to produce a larger repertoire of test lists which retained the worthwhile features of the original pair. That is, we wished to achieve a new tool with maximum interlist equivalence and high reliability, and one which would yield articulation functions with approximately the same slopes as those associated with the original test.

The difficulties which Peterson and Lehiste (2) encountered in constructing ten lists of 50 CNC words so that all lists incorporated the same phonemic balance, led us to set a goal of only four such lists. A new speech discrimination test comprising four phonemically equivalent lists has now been developed and evaluated. The test, Northwestern University Auditory Test No. 6, is described in this report.

II. NATURE OF N.U. AUDITORY TEST NO. 6

Characteristics of the word lists

In developing the two lists of words which comprise N.U. Auditory Test No. 4, Tillman et al. (4) were careful to conform as rigorously as possible to the scheme of phonemic balance advocated by Lehiste and Peterson (1). This pattern was developed by selecting all the 1,263 monosyllables of the consonant-vowel-consonant type which Thorndike and Lorge (3) listed as occurring at least once per million words. Lehiste and Peterson then determined the frequency with which each initial, medial, and final phoneme occurred in this pool of 1,263 words. They specified that each such phoneme should appear in a single list of 50 words with the same relative incidence as it exhibited in the total pool of words.

The first step in the construction of the four CNC lists which were to comprise N.U. Auditory Test No. 6 was to make the tabulation shown in table I. The table indicates the number of times each phoneme must be used in a given list if one is to preserve the phonemic distribution which characterizes the pool of 1,263 words selected initially by Lehiste and Peterson (1).

The second step was to select four mutually exclusive groups of 50 words that conformed as exactly as possible to the distributions of phonemes shown in table I. These four groupings of words appear in table II. They have been designated as lists I, II, III, and IV of N.U. Auditory Test No. 6. All but 15 of the 200 words were selected from the 500-word pool comprising the revised CNC lists published by Peterson and Lehiste (2). The remaining 15 words all appear in the larger pool of 1,263 words. Moreover, list I in table II is identical in content to list I of N.U. Test No. 4. In addition, list II in table II differs by only 4 words from the original list II (N.U. Test No. 4). Lists III and IV in the table represent two entirely new compilations.

TABLE I

The proportions (p) of incidences of phonemes which constitute the Lehiste-Peterson pattern of phonemic balance for CNC words and the number (N) of inclusions of each phoneme in each of the four lists of N.U. Auditory Test No. 6

Initial consonant				Vowel nucleus			Final consonant		
		N				N			N
Sound	p	List I	List* II, III, IV	Sound	p	All lists*	Sound	p	All lists*
p	.0642	3	3	i	.0832	4	p	.0564	3
b	.0658	3	3	I	.1116	5	b	.0264	1
t	.0578	3	3	eᴵ	.0942	5	t	.1102	6
d	.0594	3	3	ɛ	.0744	4	d	.0778	4
k	.0658	3	3	æ	.1038	5	k	.0818	4
g	.0420	2	2	ə	.0864	4	g	.0392	2
m	.0584	3	3	a	.0592	3	m	.0542	3
n	.0460	2	2	ɔ	.0626	3	n	.1054	5
f	.0452	2	2	oᵁ	.0736	4	ŋ	.0208	1
v	.0182	1	1	U	.0222	1	f	.0310	2
θ	.0118	1	1	u	.0586	3	v	.0288	1
ð	.0080	0	0	aᵁ	.0278	1	θ	.0240	1
s	.0680	3	3	aᴵ	.0736	4	ð	.0090	0
z	.0032	0	0	ɔᴵ	.0126	1	s	.0564	3
ʃ	.0354	2	2	ɝ	.0562	3	z	.0390	2
r	.0736	4	4				ʃ	.0200	1
l	.0736	4	4				ʒ	.0018	0
tʃ	.0316	2	2				r	.0628	3
dʒ	.0332	2	2				l	.1032	5
h	.0606	3	3				tʃ	.0318	2
w	.0476	1	2				dʒ	.0200	1
wh	.0156	2	1						
j	.0150	1	1						

$N = \frac{100p}{2}$ rounded to nearest integer.

*Identical to configuration associated with two lists of N.U. Auditory Test No. 4.

TABLE II

Alphabetical arrangement of CNC monosyllabic words comprising the four lists of N.U. Auditory Test No. 6

List I		List II		List III		List IV	
bean*	met	bite	merge*	bar*	mouse	back*	mob
boat	mode*	book*	mill	base*	name	bath*	mood*
burn	moon	bought*	nice*	beg	note*	bone	near
chalk	nag*	calm	numb	cab*	pain	came	neat*
choice	page	chair	pad*	cause	pearl*	chain*	pass*
death*	pool	chief	pick*	chat*	phone	check*	peg*
dime*	puff*	dab*	pike	cheek	pole	dip*	perch*
door	rag*	dead*	rain	cool	rat*	dog*	red*
fall*	raid*	deep*	read*	date	ring	doll	ripe*
fat*	raise*	fail	room	ditch*	road*	fit*	rose*
gap	reach*	far*	rot*	dodge*	rush*	food	rough*
goose	sell*	gaze	said	five*	search	gas*	sail
hash*	shout*	gin*	shack*	germ	seize	get*	shirt
home	size*	goal	shawl	good*	shall	hall	should
hurl*	sub	hate*	soap*	gun*	sheep*	have*	sour*
jail	sure	haze	south*	half	soup	hole*	such*
jar	take	hush*	thought*	hire*	talk	join	tape
keen	third	juice	ton*	hit*	team	judge*	thumb*
king	tip*	keep	tool	jug*	tell*	kick*	time*
kite*	tough*	keg	turn*	late	thin*	kill*	tire*
knock	vine*	learn	voice	lid*	void*	lean	vote*
laud	week*	live	wag*	life*	walk*	lease	wash*
limb	which	loaf	white*	luck	when	long	wheat*
lot	whip	lore	witch	mess	wire*	lose	wife*
love*	yes*	match	young	mop*	youth*	make	yearn

*Also in original PB-50 lists.

The third step in the development of N.U. Test No. 6 was to randomize each of the four parent lists four times. This procedure yielded four forms (A, B, C, D) of each of the four lists. These randomizations were subsequently recorded on magnetic tape.

Since the relative familiarity of test items is a significant variable in intelligibility testing, it is important to describe N.U. Test No. 6 in terms of this characteristic before recounting the procedure followed in recording the new test. Table III reports the number of words in each test list which fall into each of seven categories of word familiarity. Also shown in the table is analogous information based on the average of the ten Peterson-Lehiste (2) revised CNC lists. Note that the average list of N.U. Test No. 6 is quite similar to the average Peterson-Lehiste list so far as the relative distribution of test words among these seven classes is concerned. Furthermore, as was the case with the previous test (N.U. Test No. 4), the four lists of N.U. Test No. 6 include a sizeable proportion of very common words and at the same time cover a wide range of familiarity.

Recording procedures

The apparatus and technical procedure employed in storing the four lists of N.U. Test No. 6 on magnetic tape were essentially the

TABLE III

Distribution according to frequency of usage of the CNC monosyllables in N.U. Auditory Test No. 6 and in the revised Peterson-Lehiste test

Familiarity rating	List I	List II	List III	List IV	Average of four lists	Average per list for Peterson-Lehiste test
Among most common 500 words	11	13	14	14	13	10.8
Among next most common 500 words	11	9	6	12	9.5	8.4
More than 100 occurrences per million words	2	0	2	3	1.8	0.8
50 through 99 occurrences per million words	3	6	12	5	6.5	7.7
25 through 49 occurrences per million words	10	6	6	9	7.8	8.3
10 through 24 occurrences per million words	9	5	8	5	6.8	7.8
1 through 9 occurrences per million words	4	11	2	2	4.8	6.2

same as those described in relation to N.U. Test No. 4 (4). However, in order to achieve a better signal-to-noise ratio on the new test, the record gain of the tape recorder was adjusted so as to achieve a VU level of 0 dB rather than the −20-dB level used previously.

In the recording of N.U. Test No. 6, a 32-year-old male spoke the test items. In connected discourse his dialect may be described as General American, Southern Fringe (southwest Oklahoma region). Prior to this activity, he had extensive experience in the monitored live voice technic of speech audiometry. Nevertheless, he practiced extensively with the materials to be recorded prior to the final recording session.

As stated earlier, each of the four lists of N.U. Test No. 6 was prepared in four alternate forms. In order to insure equivalence from form to form in the recorded tapes, only form A of each of the four lists was actually spoken by the talker. This tape was then copied four times and through a process of cutting and splicing, master copies of each list in its four forms (randomizations) were prepared in the manner detailed in an earlier report (4).

III. METHOD OF EVALUATION

Administration of lists at selected presentation levels

Interlist equivalence, test-retest reliabilities and other characteristics of N.U. Auditory Test No. 6 were evaluated using two groups of subjects. One of these groups contained 24 normal hearing individuals while the remaining group was composed of 12 persons with sensorineural-type hearing impairments.

Each of the 36 subjects involved was examined twice. During each session, all four lists of the test were administered to the subjects six times beginning at a presentation level 4 dB *below* the subject's spondee threshold (SRT). Succeeding presentations were at progressively higher intensity levels. The rationale for this procedure was discussed in an earlier report (4).

A modified Latin-square design was utilized so as to counterbalance as completely as possible both list and form order of presentation. Since only four forms of each of the four lists were available and it was necessary to present each list a total of six times, two forms of a given list were repeated once in each test session. Care was taken to insure that a given form never recurred until three other forms of the list had intervened.

Subjects

The 24 normal hearing subjects used in the experiment were drawn from the student population at Northwestern University. The group consisted of 7 males and 17 females ranging in age from 19 to 28 years with a mean age of 21.1 years. In 12 subjects the left ear served as the test ear, while in the remaining 12 the right ear was selected for test. No subject was included who failed to respond in a screening test to pure tones from 125 through 8000 cps at a 10-dB hearing level (re ASA 1951 norm) in his test ear. The nontest ear was not held to this criterion because all measurements were conducted monaurally.

The 12 hypoacousic subjects used in evaluating Test No. 6 were drawn from the files of the Northwestern University Hearing Clinics. They were individuals who had experienced progressive hearing loss during adulthood, and they were selected primarily from the diagnostic categories of sensorineural loss and labyrinthine otosclerosis. No person was chosen as a potential subject unless his audiometric data on file in the hearing clinic indicated that his spondee threshold hearing level fell within the range of 20 to 60 dB and his discrimination score exceeded 70%. The final decision to include a subject in this group was made on the basis of audiometric tests conducted at the time of his initial visit. If the results of this examination indicated significant change in the individual's hearing since his last examination in the hearing clinic, he was not included in the experimental group.

The 11 females and 1 male finally selected ranged in age from 41 to 67 years showing an average age of 52.3 years. In all cases, the hearing loss had first been noted prior to age 50. As a group, these individuals were characterized by a mild to moderate gradually sloping, bilaterally symmetrical audiometric configuration. In those persons who showed a difference in acuity between ears, the better ear served as the test ear. Otherwise the test ear was selected arbitrarily.

Test procedures

As stated earlier, each of the 36 subjects examined in this study participated in two test sessions. Considering both groups, the interval between the test and retest sessions ranged from 6 to 17 days with a mean interval of 8.8 days. The two sessions differed from each other in only one respect—namely, the pure tone audiometry necessary for subject selection was carried out only in the initial session.

Prior to presentation of any CNC materials in either test session, the SRT for the test ear was measured after the subject had been familiarized with the spondee test vocabulary in the manner described previously (4). These materials were delivered to the subject via a speech audiometer (Grason-Stadler, model 162), calibrated to conform to the ASA norm which specifies 22 dB re: 0.0002 microbar as the strength of the signal at 0-dB hearing level. The taped test materials were reproduced by a tape recorder (Ampex, model 351-2) whose output drove the external input to one of the channels of the speech audiometer. In all instances, the level of the 1000 cps calibration tone, recorded on the tapes at the level of the test materials, was set so that the VU meter of the speech audiometer registered 0 dB. Actual determination of the SRT followed the procedure described below.

An initial presentation level, 10 to 20 dB above the estimated SRT, was selected and two test words were presented at this level. The initial presentation level was selected so that the subject correctly repeated a minimum of five of the first six test items. In the event that this criterion was not met with the initial selection of a starting level, a higher presentation level was chosen and the test run was begun anew. The intensity of the signal was then attenuated by 2 dB and two more words were presented. This procedure was continued until the subject either failed to respond or responded incorrectly to six consecutive test words. Threshold was then computed by subtracting the number of words correctly repeated from the intensity of the signal at the starting level and then adding 1 dB to compensate for the fact that the 50%-criterion is not fully met via this procedure.

In each test session, the spondee threshold was established in two consecutive runs and the lower (better) of the two values was accepted as the reference level from which to present the CNC words. Since the attenuator of the speech audiometer was calibrated in 2-dB steps, in the case of an odd-integer spondee threshold, the reference intensity used was the level 1-dB higher than the actual SRT.

The next step in the procedure involved the measurement of discrimination scores for each of the four test lists. As stated earlier, the sensation levels of presentation were expressed relative to the SRT measured in the particular session. That is, in the event of a change in the SRT from test to retest, the new level, regardless of whether it was higher or lower than the initial SRT, served as 0-dB sensation level in the retest session. The six sensation levels at which the CNC materials were presented were: —4, 0, 8, 16, 24, and 32 dB. As stated previously, so far as possible, the order of presentation of lists and forms was rotated over subjects to guard against systematic order effects. However, for a given subject, the same sequence of presentation was followed in the two test sessions.

IV. RESULTS

Articulation functions for normal hearing subjects

Table IV displays the data obtained with normal hearing subjects during the first test run, while table V summarizes the like information obtained in the retest session. In these two tables, means, medians, and standard deviations of discrimination scores are reported separately for each of the four lists at each presentation level. The mean values reported in these two tables are displayed in graphic form in figure 1. Since the data points clustered within a relatively narrow range of discrimination scores, a single articulation function was utilized to describe them (see fig. 1).

The data in tables IV and V and in figure 1 reveal that the four lists yielded articulation functions of essentially equivalent slope. Further, it is apparent that for a given list, the slope of the function changed little from test to retest.

TABLE IV

Median (Med), mean (M), and standard deviations (SD) of discrimination scores obtained with N.U. Auditory Test No. 6 for subjects with normal hearing during the first test session (scores represent percent of items correctly repeated)

Sensation level of presentation*	List I			List II			List III			List IV		
	Med	M	SD	Med	M	SD	Med	M	SD	Med	M	SD
—4	6	8.2	8.2	8	9.4	9.8	6	6.7	5.9	6	8.8	7.7
0	29	30.9	14.1	24	28.1	16.1	25	25.7	10.8	32	31.1	15.3
8	74	70.8	14.3	72	72.3	12.1	74	73.8	9.4	77	74.1	10.6
16	89	88.6	10.6	93	91.3	7.2	94	92.3	5.3	94	92.5	6.1
24	98	96.0	5.2	98	97.8	2.8	99	96.6	3.1	98	97.7	2.8
32	100	98.6	3.8	100	99.3	1.5	100	99.6	1.0	100	99.5	2.4

*Mean SRT = 21.9 dB SPL re: 0.0002 microbar.

TABLE V

Median (Med), mean (M), and standard deviations (SD) of discrimination scores obtained with N.U. Auditory Test No. 6 for subjects with normal hearing during retest session (scores represent percent of items correctly repeated)

Sensation level of presentation*	List I			List II			List III			List IV		
	Med	M	SD	Med	M	SD	Med	M	SD	Med	M	SD
−4	6	8.2	7.7	7	8.7	9.0	3	5.8	5.9	6	8.1	7.4
0	32	31.5	13.0	38	37.4	13.1	30	29.6	12.9	33	34.1	13.0
8	76	75.8	10.0	81	79.8	6.8	84	79.6	11.1	77	77.8	9.8
16	94	92.0	5.4	94	94.4	3.6	94	94.2	3.5	96	94.0	6.8
24	98	97.5	2.4	100	98.9	2.0	98	98.3	2.0	100	97.8	4.4
32	100	99.7	1.0	100	99.8	0.7	100	99.3	2.2	100	99.2	3.3

*Mean SRT = 21.2 dB SPL re: 0.0002 microbar.

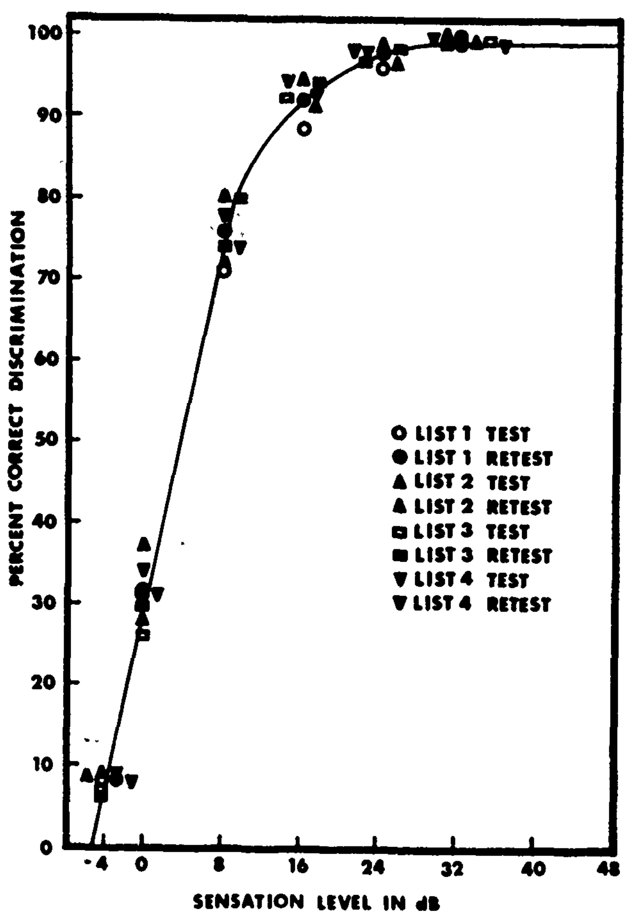

FIGURE 1

Mean discrimination scores yielded by normal hearing group for lists I, II, III, and IV during both test and retest sessions. A single articulation function fits all sets of data.

As was the case with N.U. Auditory Test No. 4 (4), the characteristic feature of the curve in figure 1 is that it represents a linear function which undergoes saturation. The lower segment of the curve is linear and rises at the rate of approximately 5.6% per decibel increase in signal presentation level. The linear segment appears to terminate at a sensation level of about 9 dB where the average discrimination score approaches 80%. These characteristics are almost identical to those of the earlier test (N.U. Test No. 4). As was also the case with this latter test, the upper portion of the function in figure 1 describes a curvilinear progression in which scores increase less and less with progressive elevation in signal strength, finally reaching an asymptote, characterized by almost perfect discrimination. This asymptote is not reached until a presentation level of 32 dB is achieved. With the previous test (N.U. Test No. 4) the asymptotic level was reached at the 24-dB sensation level.

Another way of considering the features just discussed is to examine the variability of scores at the different presentation levels (see tables IV and V). In this consideration the values at the −4-dB sensation level are excluded, since at this level the range of scores was restricted by the fact that negative scores cannot occur and the standard deviation is, therefore, not an adequate measure of variability. Note, however, that at the 0-dB and 8-dB sensation levels, both of which fall within the linear portion of the articulation functions, the variability of the discrimination scores was great. Observe further that as the stimulus intensity became high enough to saturate the curve with correct responses, variability decreased markedly and systematically. In fact, as the asymptote of the function is approached—i.e., at 32-dB sensation level—the standard deviations approach zero, ranging from 0.7% to 3.8%. At this level, variation in response among normal hearing subjects is probably due predominantly to occasional errors arising from lack of attention, masking produced by head movement or vocal productions and other secondary factors.

As emphasized above, the important features of the articulation functions for N.U. Test No. 6 were essentially invariant from list to list and from test to retest. It is true that careful examination of the data presented so far reveals that minor changes in performance did occur as a consequence of both these variables. However, it may be stated that the characteristics of N.U. Test No. 6, as these reveal themselves through data collected from normal hearing subjects, are almost identical to those of N.U. Test No. 4 (4). In fact, the articulation function for these latter materials is not shown in figure 1 because it would be essentially indistinguishable from the curve displayed there.

Articulation functions for subjects with sensorineural loss

Our previous experience with N.U. Test No. 4 had revealed that the basic pattern of the articulation function for subjects with conductive hearing losses was essentially the same as that for normal subjects. Thus, in the evaluation of N.U. Test No. 6 a sample of subjects with conductive losses was not included. However, since subjects with sensorineural hearing impairment had differed markedly from those of normal subjects when exposed to Test No. 4, the various lists of Test No. 6 were administered to a group of subjects with sensorineural impairment. The data yielded by these subjects in the test and retest sessions are summarized in tables VI and VII. The mean data from these two tables are displayed graphically in figure 2. In two respects, these data closely approximate those reported earlier for the normal hearing subjects. However, one also notes three major discrepancies.

As was the case with the normal hearing group, the articulation functions yielded by the hypoacousic subjects for the four lists are

TABLE VI

Median (Med), mean (M), and standard deviations (SD) of discrimination scores obtained with N.U. Auditory Test No. 6 for subjects with sensorineural hearing loss during the first test session (scores represent percent of items correctly repeated)

Sensation level of presentation*	List I			List II			List III			List IV		
	Med	M	SD	Med	M	SD	Med	M	SD	Med	M	SD
−4	7	7.5	6.3	4	8.8	9.8	3	6.0	7.1	8	8.2	7.2
0	16	16.8	10.7	18	20.7	14.7	11	16.7	13.1	18	17.3	12.5
8	55	49.0	17.5	49	47.3	19.6	41	41.0	17.3	49	46.2	16.1
16	75	71.0	16.2	74	71.3	18.2	74	67.2	24.1	78	70.8	17.3
24	87	85.8	9.2	91	87.3	10.2	84	81.8	13.9	93	89.2	9.3
32	91	90.7	5.3	96	93.2	6.5	92	89.3	8.5	96	93.3	5.1

*Mean SRT = 57.5 dB SPL re: 0.0002 microbar.

TABLE VII

Median (Med), mean (M), and standard deviations (SD) of discrimination scores obtained with N.U. Auditory Test No. 6 for subjects with sensorineural hearing loss during the retest session (scores represent percent of items correctly repeated)

Sensation level of presentation*	List I			List II			List III			List IV		
	Med	M	SD	Med	M	SD	Med	M	SD	Med	M	SD
−4	5	7.0	7.2	7	9.7	10.2	1	4.7	9.6	8	8.8	7.7
0	21	19.8	11.3	17	21.0	10.7	10	14.5	10.5	16	17.3	10.4
8	57	53.5	20.5	61	54.8	17.7	38	42.2	21.2	47	48.0	18.4
16	82	74.5	16.4	82	77.5	15.1	76	67.7	21.4	80	73.7	17.9
24	90	85.7	12.8	94	91.0	6.7	87	81.5	17.5	94	87.5	12.3
32	93	90.7	10.4	95	93.0	5.7	92	86.0	18.5	97	92.8	8.2

*Mean SRT = 56.5 dB SPL re: 0.0002 microbar.

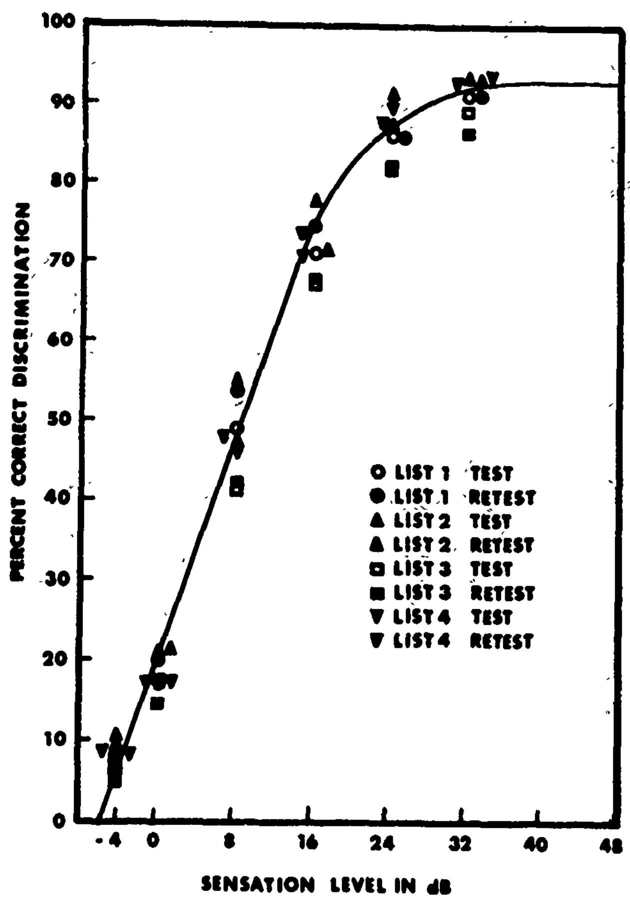

FIGURE 2

Mean discrimination scores yielded by subjects with sensorineural hearing loss for lists I, II, III, and IV during both test and retest sessions. A single articulation function fits all sets of data.

highly equivalent to one another in configuration. In fact, a single function describes the entire array of data points rather well (see fig. 2). As was true with the normal group, the pattern of the articulation functions for the sensorineural group also bespeaks a saturation curve with the point of nonlinearity occurring at a score of approximately 74% (16-dB SL). Recall that this point occurred at about 80% (SL = 9-dB) for the normal group.

The first discrepancy between the results for the normal group and the sensorineural group concerns the slope of the articulation functions for the various lists. While the linear portions of the functions yielded by the normal hearing subjects rose at the rate of about 5.6% per decibel increase in signal intensity, the functions for the hearing impaired group sloped more gradually, approximately 3.4% per decibel in the linear segment. As a concomitant, the nonlinear upper segments of the functions for the sensorineural group do not reach full saturation within the range of presentation levels employed in this experiment. At the maximum level, 32-dB SL, the average score was approximately 91%. If one extrapolates the functions as has been done in figure 2, it appears that the average saturation asymptote would occur at a mean discrimination score of approximately 93% and that this mean score would have occurred at a sensation level of about 40 dB.

A second feature which distinguishes the results for the sensorineural group from those for the normal group concerns the variability of the discrimination scores about the mean values at the various presentation levels. At the 8-dB sensation level and above, the inter-subject variability in performance, as estimated by the standard deviation of the responses, was much greater for the hypoacoustic group than for the normal group. This fact merely emphasizes that, as a group, the hearing impaired subjects were much less homogeneous in discriminatory capacity than were the normal hearers.

The third and perhaps the most significant difference between the results of these tests for the two groups studied concerns the group performance from list to list. Recall that, for the normal listeners, only minor differences in group performance occurred in this regard. However, in the sensorineural group, although the functions for the various lists rose with approximately the same slope, they seemed to be slightly displaced from one another on the sensation level scale. For example, the function for list II would appear to be shifted somewhat further to the left than the other three while that for list III seems to be displaced to the right of the other functions. These circumstances suggest, of course, that the close interlist equivalence, apparent from a study of the data from the normal hearing group, is not completely preserved when the tests are administered to subjects with sensorineural hearing impairment. This discovery is hardly surprising when one considers the effects which variations in the audiometric configuration and other features of hearing loss may exert. The important point to make is that the N.U. Auditory Test No. 6 possesses good interlist equivalence as judged from the performance of the present hypoacousic sample, and this picture is not likely to change significantly as other samples are evaluated.

Test-retest relationships

Two important relationships emerge from a study of the test-retest data yielded by the two subject groups. First, there was a highly systematic tendency for discrimination scores to improve slightly from test to retest. This trend was particularly apparent within the range of sensation levels where the articulation functions were linear. Second, test-retest reliability was good.

Table VIII allows one to evaluate the absolute differences between mean performance from test to retest. Note that for both subject groups, the maximum test-retest difference is less than 10% and only 4 out of 48 times did it exceed 6%. Furthermore, for the normal group only 4 of the 24 test-retest differences were found to be statistically significant. Similarly, only 3 of the differences between test-retest performance proved to be statistically significant for the sensorineural group. It is interesting to note that 6 of these 7 significant outcomes are associated with list II which, for the sensorineural group at least, appeared to be the easiest of the four lists.

On the basis of the data from this experiment, it is impossible to say whether the improvement in performance from test to retest occurred in consequence of practice in the task involved or of increase in familiarity with the test vocabulary. Be that as it may, the data in table VIII allow one to conclude that with this test the differences in performance from test to retest are not sufficiently large to cause major concern. Recall that, within the linear segment, the articulation functions for the normal and sensorineural subjects rose at rates of 5.6% and 3.4% per decibel, respectively. Thus, the mean changes in performance from test to retest were of the order of magnitude which would have been produced by a 1- to 2-dB increase in signal presentation level (see table VIII). With N.U. Test No. 6, as with its predecessor (N.U. Test No. 4), one can thus have confidence in the discrimination score that is obtained when a particular form of any of the four lists must be used a second time. This conclusion, of course, implies that the experimenter will take care to insure that a given list is not repeated over and over in the same form or without other lists intervening between successive presentations of a given list.

The test-retest reliability of the four lists of N.U. Test No. 6 can be judged by a study of the correlation coefficients shown in table IX. If one disregards the data for the —4-dB sensation level, where the distribution of scores was obviously truncated, and confines attention to the data obtained in the remainder of the region where the articulation function rose with a linear slope, the following facts emerge. First, in the normal hearing group the correlations are all positive and they range from a low of .27 to a high of .59. Secondly, in the sensorineural group, the correlations are again all positive and generally much higher, ranging from .36 to .93. This difference between the two groups is undoubtedly related to the fact that the range of discriminatory capacities in the normal group was quite restricted relative to that of the sensorineural group. Other things being equal, such a restriction in the range of the characteristic under study tends to reduce the magnitude of the Pearson r.

TABLE VIII

Difference between mean discrimination scores from test to retest at the several presentation levels for the two groups on N.U. Auditory Test No. 6 (negative difference indicates higher score in retest than in test session)

Sensation level of presentation	Normal hearing group				Sensorineural loss group			
	List I	List II	List III	List IV	List I	List II	List III	List IV
−4	−0.1	0.8	0.8	0.8	0.5	−0.8	1.3	−0.7
0	−0.6	−9.3*	−3.9	−3.0	−3.0	−0.3	2.2	0.0
8	−4.9	−7.5†	−5.8*	−3.7	−4.5	−7.5†	−1.2	−1.8
16	−3.4	−3.1*	−1.9	−1.5	−3.5	−6.2*	−0.5	−2.8
24	−1.5	−1.2	−1.8	−0.2	0.2	−3.7*	0.3	1.7
32	−1.1	−0.4	0.2	0.3	0.0	0.2	3.3	0.5

*t statistic associated with difference equals or exceeds that required for significance at 5% confidence level.

†t statistic associated with difference equals or exceeds that required for significance at 1% confidence level.

TABLE IX

Coefficients of correlation (Pearson r) between test and retest for N.U. Auditory Test No. 6 administered to subjects with normal hearing and subjects with sensorineural hearing loss*

Sensation level	Normal hearing group				Sensorineural loss group			
	List I	List II	List III	List IV	List I	List II	List III	List IV
−4	.30	.29	.34	.15	.59	.84	.74	.48
0	.41	.35	.41	.36	.47	.72	.62	.50
8	.54	.27	.43	.59	.93	.92	.83	.79
16					.92	.86	.93	.91

*For each group, analysis is restricted to the range of sensation levels within which the slopes of the articulation functions were judged to be linear.

The array of test-retest correlations shown in table IX compares favorably with that associated with N.U. Auditory Test No. 4 (4). Moreover, the various values reported in the table are of the general order of magnitude usually considered to indicate acceptable test-retest reliability.

V. CONCLUSIONS

On the basis of the material presented here, we conclude that we have achieved the goal that we were seeking. It seems clear that N.U. Auditory Test No. 6 compares favorably with its predecessor (N.U. Test No. 4) in inter-list equivalence and test-retest reliability. In addition, the new tool yields articulation functions which rise with approximately the same slope as those associated with the original test. As stated earlier, N.U. Test No. 4 has proved to be a highly useful tool for the measurement of phonemic discrimination in the laboratory as well as in the clinical setting. We thus expect N.U. Test No. 6, which possesses twice the vocabulary of the original test, to be a valuable addition to the armamentarium of the audiologist.

REFERENCES

1. Lehiste, I., and G. E. Peterson. Linguistic considerations in the study of speech intelligibility. J. Acoust. Soc. Amer. 31:280-286 (1959).

2. Peterson, G. E., and I. Lehiste. Revised CNC lists for auditory tests. J. Speech Hearing Dis. 27:62-70 (1962).

3. Thorndike, E. L., and I. Lorge. The teacher's word book of 30,000 words. New York: Columbia University Teachers College, 1944.

4. Tillman, T. W., R. Carhart, and L. Wilber. A test for speech discrimination composed of CNC monosyllabic words (N.U. auditory test No. 4). SAM-TDR-62-135, Jan. 1963.

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) Auditory Research Laboratory Northwestern University Evanston, Ill.	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

AN EXPANDED TEST FOR SPEECH DISCRIMINATION UTILIZING CNC MONOSYLLABIC WORDS: N.U. AUDITORY TEST NO. 6

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
16 Jan. 1964 - 15 Apr. 1965

5. AUTHOR(S) (Last name, first name, initial)
Tillman, Tom W.
Carhart, Raymond

6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1966	12	4

8a. CONTRACT OR GRANT NO. AF 41(609)-2643 b. PROJECT NO. c. Task No. 775508 d.	9a. ORIGINATOR'S REPORT NUMBER(S) SAM-TR-66-55 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES
Distribution of this document is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	USAF School of Aerospace Medicine Aerospace Medical Division (AFSC) Brooks Air Force Base, Tex.

13. ABSTRACT

Northwestern University Auditory Test No. 6 is composed of four lists of 50 consonant-nucleus-consonant (CNC) monosyllabic words each. The construction of the test followed the same scheme employed earlier in the development of N.U. Test No. 4, a less extensive version using the same type of material. The four lists of N.U. Test No. 6 were given twice to each of two subject groups--one group with normal hearing and another with sensorineural hypoacousis. During each administration, six ascending presentation levels were used ranging from -4-dB to 40-dB sensation level.

The two groups yielded articulation functions highly similar to those obtained with the earlier test (N.U. Test No. 4). The new test (N.U. Test No. 6) appears to have good interlist equivalence and high test-retest reliability. It thus retains the desirable features of the earlier tool while doubling the inventory of items available for the measurement of phonemic discrimination.

Unclassified

Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Otolaryngology						
Audiology						
Speech discrimination						
Articulation function						
CNC words						
N.U. Test No. 4						
N.U. Test No. 6						

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year; or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
_______________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
_______________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
_______________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS), (S), (C), or (U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.